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Gauss et al.

[11] **4,086,596**

[45] **Apr. 25, 1978**

[54] **WHIP ANTENNA ASSEMBLY AND METHOD OF MANUFACTURE**

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[73] Assignee: **Motorola, Inc.,** Schaumburg, Ill.

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[51] **Int. Cl.**[2] **H01Q 1/32;** H01Q 9/18

[52] **U.S. Cl.** **343/715;** 343/749

[58] **Field of Search** 343/715, 749, 895, 873, 343/900

[56] **References Cited**

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Attorney, Agent, or Firm—Victor Myer; James W. Gillman

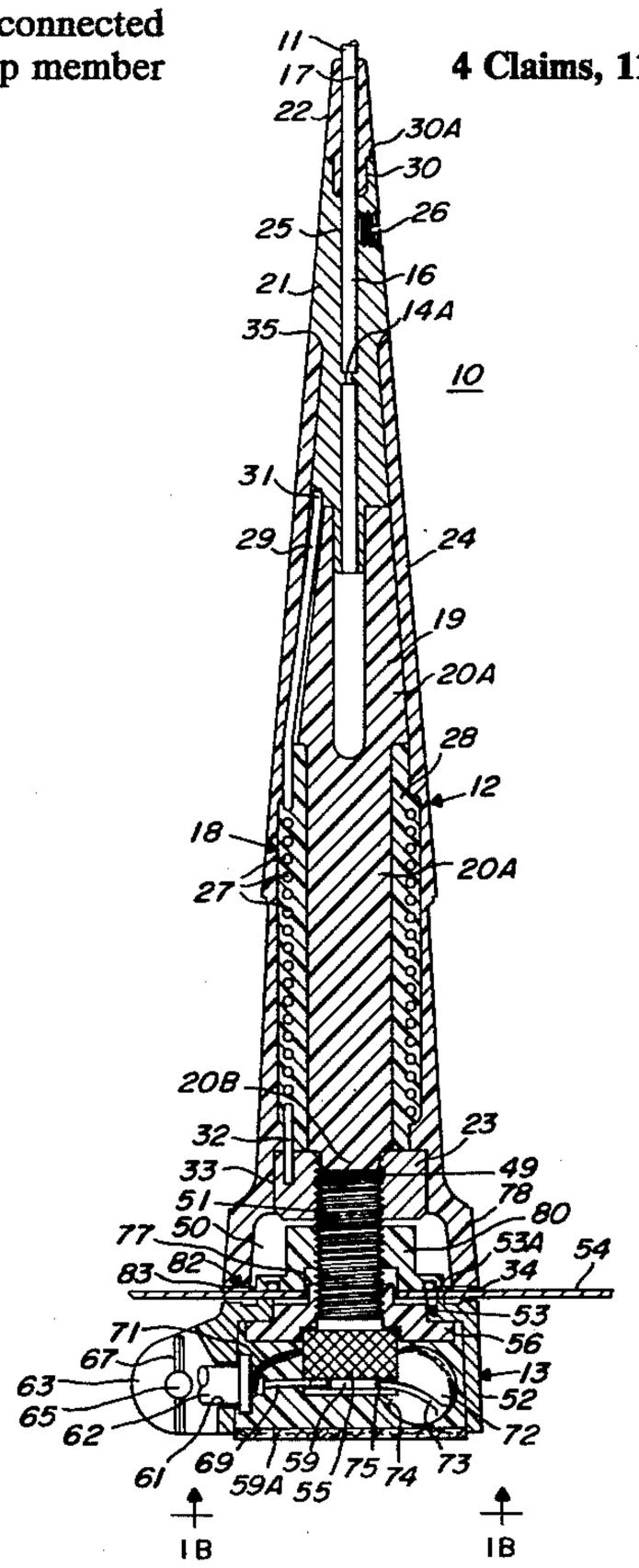
[57] **ABSTRACT**

There is disclosed an antenna including an accurately formed whip member and an accurately formed loading coil one end of which is connected to one end of the whip member and the other end of which is connected to a single connector. The length of the whip member and its diameter and any associated metallic connector are selected to give a predeterminedly accurate capacitive value. The loading coil has a predeterminedly accurate inductive value such that the loading coil and whip member have a net accurate inductive value which is connected to a predeterminedly accurate capacitor for matching the impedance of the antenna to the conductor, coaxial cable for example, from the transmitter. The capacitor, a single stub connector, the end of the coaxial cable and the necessary connections are epoxy encapsulated in a base housing.

The connector at the end of the loading coil is attached to the single stub connector in the base to provide the only connection necessary for the antenna to become operative.

The loading coil is very accurately formed by a two-step molding process wherein the turns are first held in position by a first molding step followed by a second overmolding step which connects and holds the associated parts together. The overall accuracy thus obtained is such that no adjustments in the factory after assembly, nor in the field are necessary and the voltage standing wave ratio of the antenna throughout the operating frequency band (Citizens Band) is no greater than two to one.

4 Claims, 11 Drawing Figures



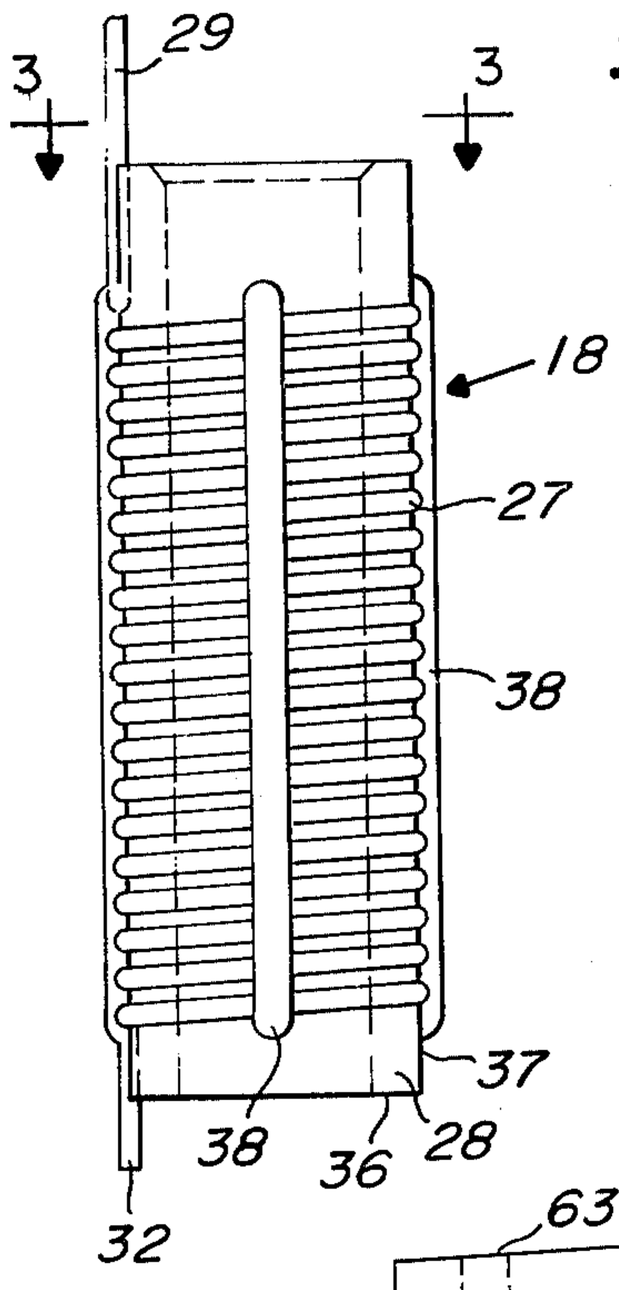


Fig. 2

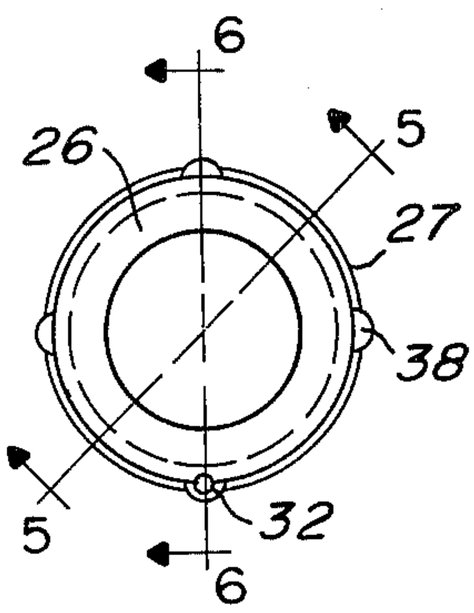


Fig. 3

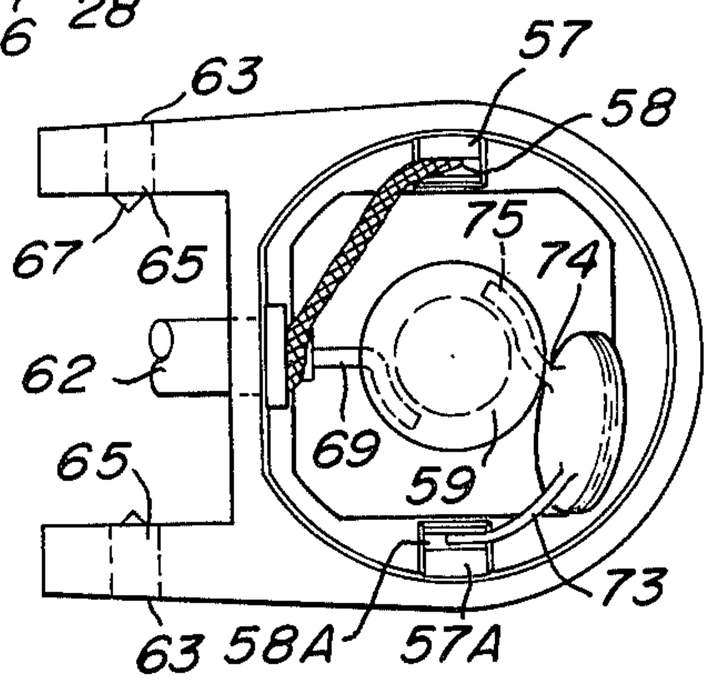


Fig. 1B

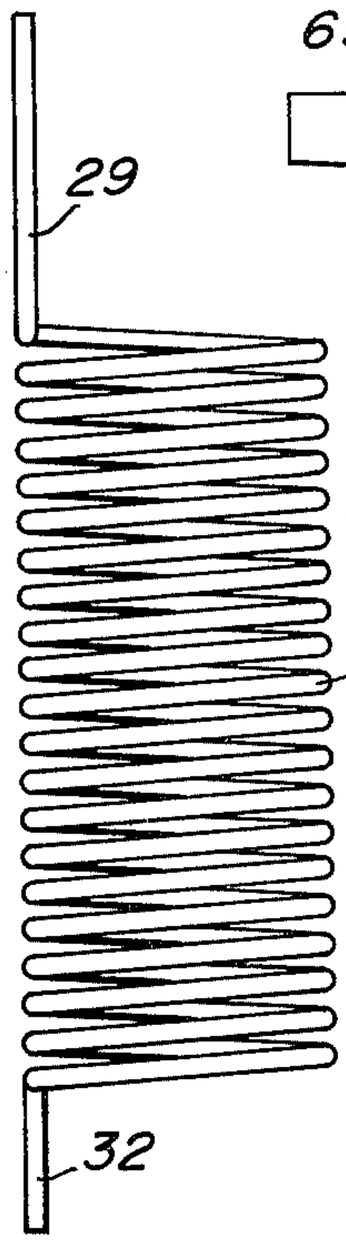


Fig. 4

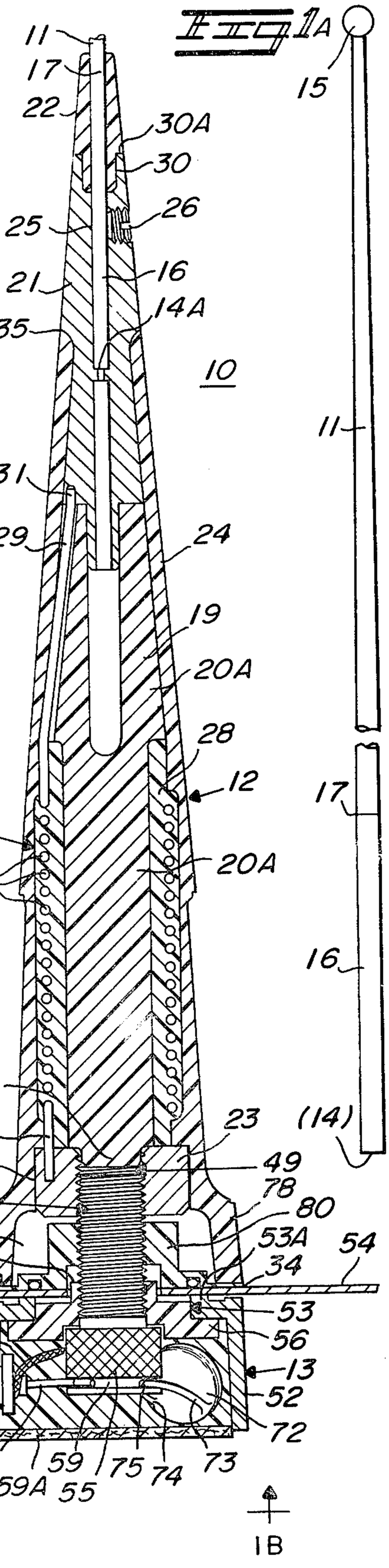


Fig. 1

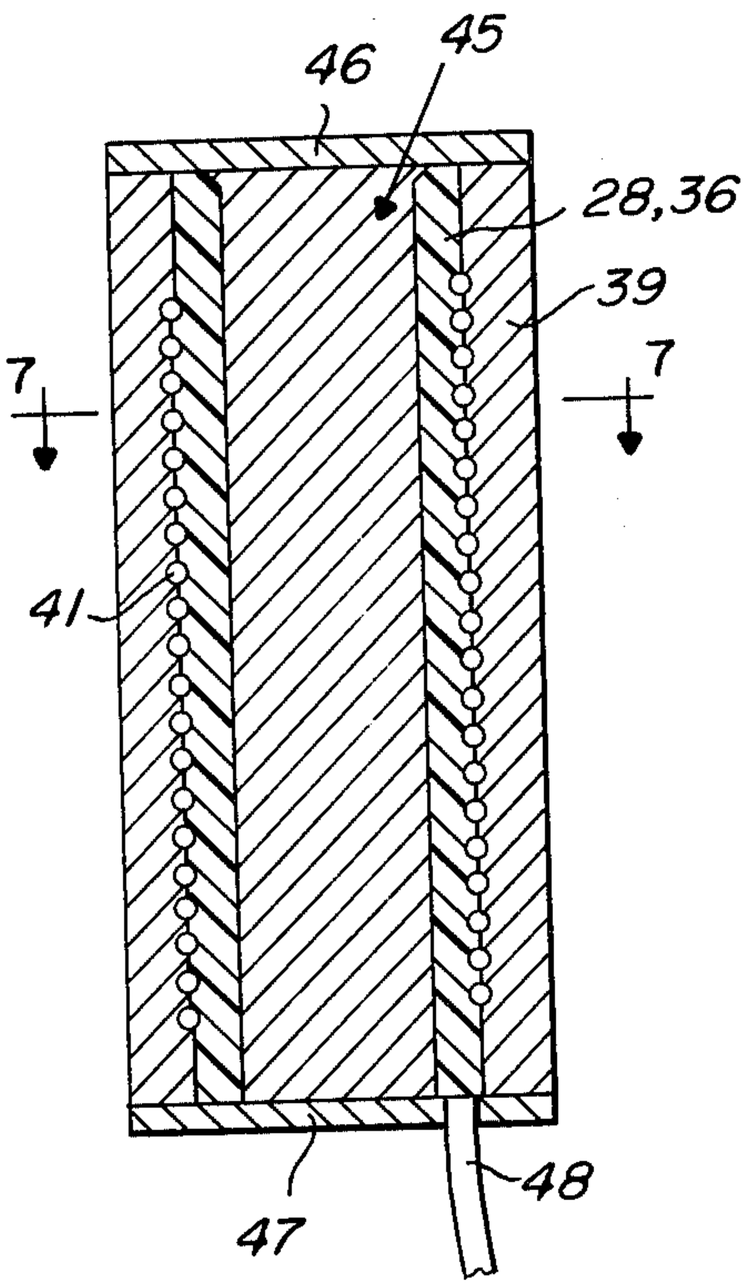


Fig. 5

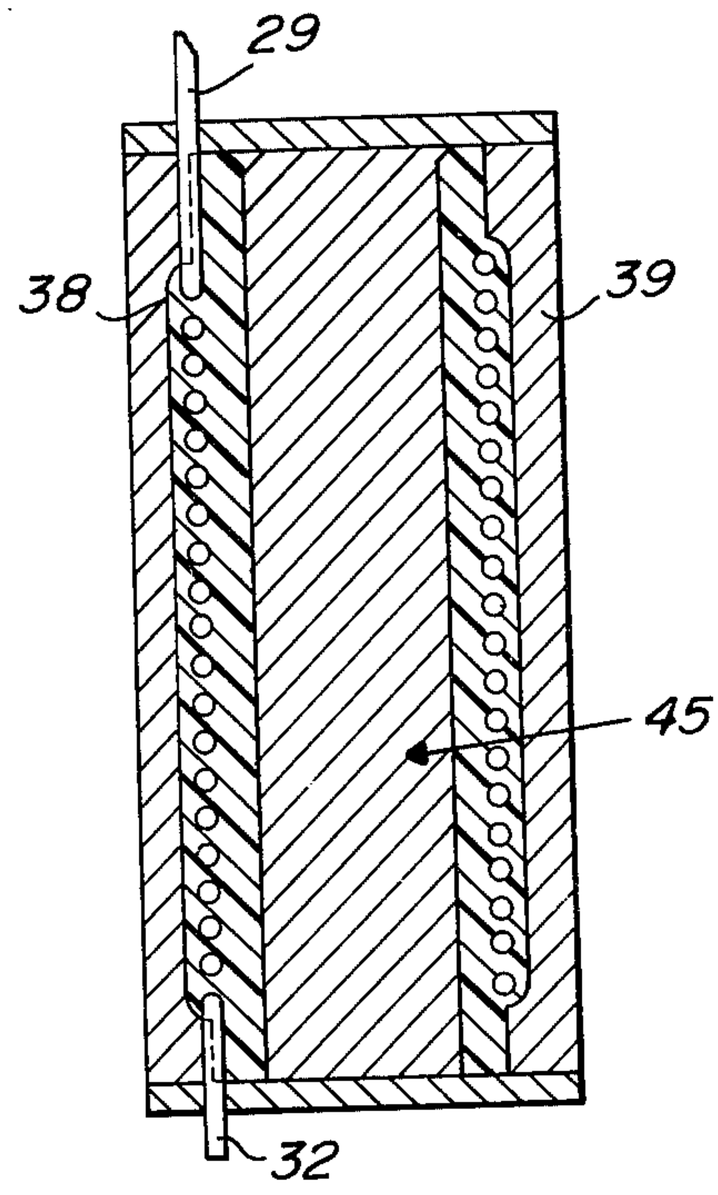


Fig. 6

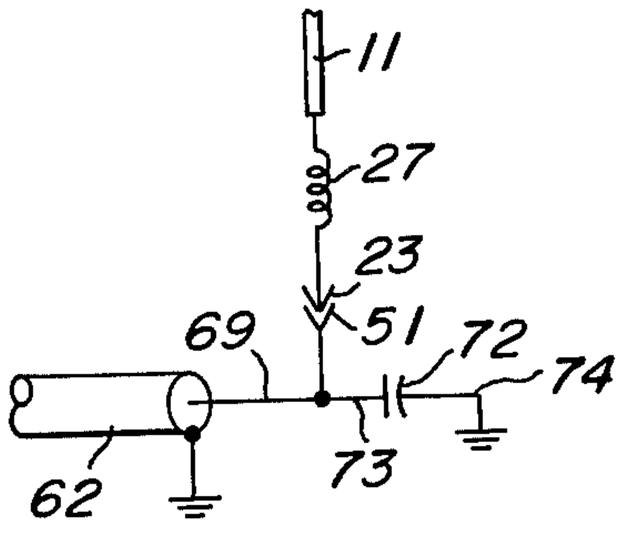


Fig. 8

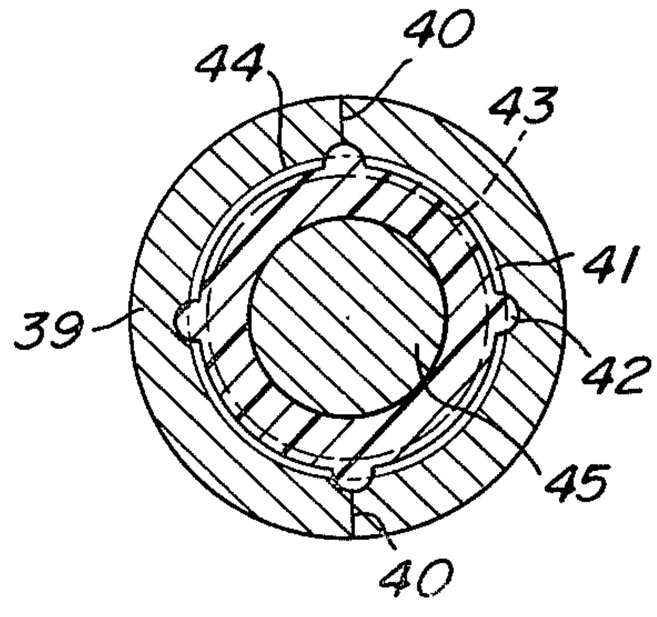


Fig. 7

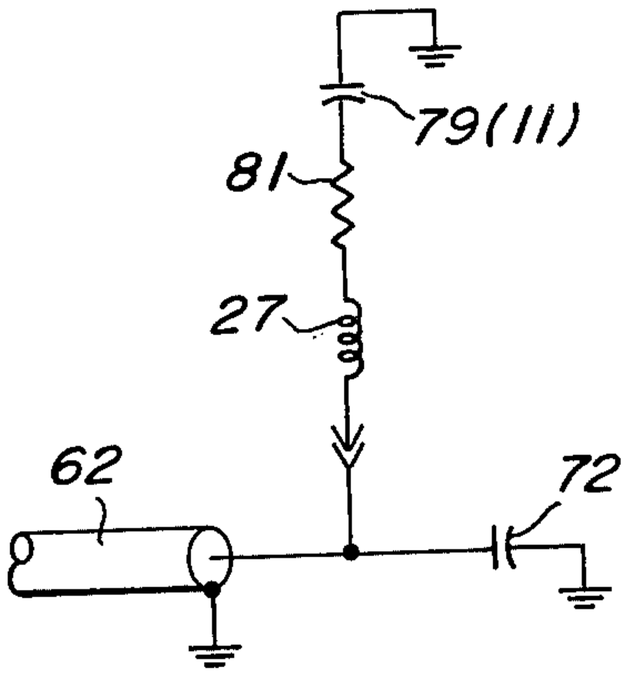


Fig. 9

WHIP ANTENNA ASSEMBLY AND METHOD OF MANUFACTURE

RELATED APPLICATIONS

This application is related to the application of Robert C. Gauss and Lynn D. Wills, filed Mar. 22, 1976 Ser. No. 668,944, entitled "Encapsulated Antenna Base", and assigned to the same assignee as the subject invention.

BACKGROUND OF THE INVENTION

This invention relates to mobile antennas and more particularly to such mobile antennas which when formed of a whip member and a loading coil do not require any adjustment, either at the factory, or at the installation, when connected by virtue of a single connector to a mounting base in order to maintain a low voltage standing wave ratio across the frequency band desired for example the Citizens Band frequency range.

In past constructions when a whip member has been cut to a given length and connected to its receptacle including a loading coil, individual adjustment has been necessary at the factory, or at the installation, in order to maintain the appropriate value of voltage standing wave ratio. More than one connection from the loading coil to the base has been necessary and the constructions have been susceptible to vibrations, shocks, etc., whereby reception by the antenna has been poor and the constructions have been expensive to fabricate.

SUMMARY OF THE INVENTION

It is an object of the invention to provide an improved base, loading coil mobile antenna which overcomes the objections of the prior art constructions.

It is a further object of the invention to provide an improved antenna of the nature indicated which does not require any adjustment after the final assembly steps have been taken.

It is a further object of the invention to provide an improved antenna of the nature indicated which is efficient, requires no final adjustment, and is inexpensive to manufacture.

In carrying out the invention in one form there is provided an antenna for a predetermined frequency band comprising in combination, a predetermined length of whip member and a loading coil of predetermined inductance value connected to the whip member for providing a precise inductive impedance of the whip and coil for matching to a transmission line with a standing wave ratio of a value no greater than about 2:1 throughout the band.

In carrying out the invention according to another form there is provided a method of forming an antenna for a predetermined frequency band comprising the steps of providing an accurate whip member of predetermined length, providing a loading coil having a predetermined number of turns, a predetermined diameter of turns, and a predetermined diameter of wire, interiorly molding said turns against the interior screw surface of a mold whose threads have the same diameter, pitch and groove diameter as the corresponding dimensions of the coil, providing an interconnecting metal member between one end of the whip member and one end of said coil, overmolding the assembly of the loading coil and the metal member and attaching the whip member to the metal member.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an elevational view partially in section of an antenna construction according to the invention;

FIG. **1A** is an elevational view of the antenna whip;

FIG. **1B** is a bottom view taken substantially in the direction of arrows **1B—1B** of FIG. **1**;

FIG. **2** is an elevational view of the loading coil utilized in the invention in a preliminary stage;

FIG. **3** is an end view of the preliminary stage coil taken substantially in the direction of arrows **3—3** of FIG. **2**;

FIG. **4** is a diagrammatic view of a spiral coil of wire wound according to the invention;

FIG. **5** is a diagrammatic sectional view of a mold for the first step molding of a coil and would be taken essentially in the direction of arrows **5—5** of FIG. **3**, when the coil was in the mold;

FIG. **6** is a diagrammatic sectional view similar to FIG. **5** but which would be taken in the direction of arrows **6—6** of FIG. **3** when the coil was in the mold;

FIG. **7** is a sectional view taken substantially in the direction of arrows **7—7** of FIG. **5**;

FIG. **8** is a circuit diagram showing an antenna connected to the conductor from the transmitter; and

FIG. **9** is a circuit diagram representing the antenna circuit.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings, there is shown an antenna **10** comprising a whip **11**, a loading coil assembly **12** and a base **13**.

The whip **11** is the main radiating portion of the antenna and comprises a stainless steel wire or rod, having a conducting layer, for example, copper, plated thereon, the antenna whip appearing black because the copper is given an oxide treatment for weather protection and appearance. The length of the whip may be of any value desired for particular conditions but in the particular case wherein the antenna is used in the Citizen Band range the length from end **14** to point **15** is 49.25 inches. The end **16** for a distance of about 19½ inches to point **17** has a diameter of 0.100 inch and from point **17** to end **15** there is a straight taper from 0.100 inch to 0.048 inch at end **15**.

The loading coil assembly **12** comprises a coil of copper wire **18**, a central supporting and stiffening member, or insert **19**, an antenna rod clamp **21**, a flexible collar **22**, a threaded base nut **23**, and an overmolded cover **24**.

The insert **19** is formed as a separate molded part having a tapered portion **20** and a shank portion **20A**.

The whip **11** is received through a central bore in the collar **22** and into a central bore **25** in the antenna clamp **21** until the end **14** reaches the shoulder **14A** as shown, the whip being held in the clamp **21** by some means, such, for example, as a set screw **26**.

The coil **18** comprises an accurate number of turns of wire **27** which are accurately held as by an injection molding process in a molded sleeve **28**, one end **29** extending up to and firmly connected, as by crimping, in a hole **31** at the lower end of antenna clamp **21**, the other end **32** of the coil extending downwardly and being firmly held as by crimping in a hole **33** formed in the base nut **23**. Thus a continuous electrical circuit will extend from the base nut **23** through the coil end **32**, the turns of **27** of the coil, the end **29**, the antenna clamp **21**,

and to the antenna whip **11**. Surrounding and firmly holding in precise relationship the base nut **23**, the coil **18**, the insert **19**, and the antenna clamp **21** is the molded cover **24** extending as shown from the point **34** to the point **35**.

It is an important feature of the invention that once the antenna has been assembled at the factory, no adjustment is required, either at the factory, or at the installation in order to maintain the low value of voltage standing wave ratio (VSWR) across the band, namely the Citizens Band in the present instance. This requires accuracy at all stages of manufacture including the length of the antenna whip **11**, the dimensions of the antenna clamp, and the dimensions and other constants of the coil **18**.

The loading coil assembly **12** is formed in a two step molding process wherein a coil of wire **27** is first molded into a coil including the support member **28** to give an assembly **18** which in the final process is over molded by the cover **24**, the second molding step.

Referring to FIGS. **2** through **7** inclusive the construction of coil **18** in its preliminary or first molding stage may be understood. The coil **18** in this preliminary state comprises the coil of wire **27** molded onto a support member (sleeve) **28** to form an integral separate unit **18** as may be seen best in FIG. **2**. The support **28** is essentially a hollow cylindrical core **36** in the outer surface **37** of which the turns **27** are partially embedded. Spaced equidistantly around the core **28** are four longitudinally extending embossments **38** which are integrally molded with the core **36** and the upper surfaces of which extend above the outer extremities of the turns **27**. Extending from one end of the turns or coil **27** is the terminal end **29** and extending from the other end of the turns **27** is the terminal end **32**. By virtue of the turns **27** being partially embedded in the outer surface of the core **36** and by the embossments **38**, the turns **27** are rigidly held in their precise position of spacing between turns. The inductance value of the coil can thus be very accurately predetermined. Construction of the coil **18** to the extent described is known in the art and as such is not part of the invention except as it enters into the complete combination being described.

In FIG. **4** the turns **27** are shown wound in the same manner as a coil spring. The size of the wire, the diameter of the turns, the spacing of the turns, and the lengths of the ends **29** and **32** have been accurately predetermined in order to give the desired inductive value. The series of turns **27** is then placed inside of a cylindrical member or cavity **39** (FIGS. **5**, **6**, and **7**) which has spiral grooves **41** disposed on its interior surface which conform to the wire size, turn diameter, and spacing between turns of the turns **27**. Thus the turns **27** when disposed interiorly of the cavity **39** are held within the spiral grooves **41**. Also interiorly of the cylindrical cavity **35** are four longitudinally disposed grooves **42** (FIG. **7**) which form the embossments **38**. In FIG. **7** the dotted circle **43** represents the inside diameter of the turns of wire **27** and thus represents the extent of embedment of the turns of the core member **36**. In this same figure the circle **44** represents the outside diameter of the groove in the cylindrical mold **35** and also represents the exterior diameter of turns **27**. The mold may be split at the lines **40** for permitting removal of the molded coil.

After the series of turns **27** (coil) has been disposed inside of the cylindrical cavity **39**, a central core member **45** of appropriate diameter is disposed centrally of the molding cavity, and as shown diagrammatically, closing end members **46** and **47** are appropriately disposed to close the molding cavity. Thereafter molding compound such as acrylonitrile — butadiene — styrene, for example, is injected under pressure through an appropriate opening **48** to form the completed coil **18** as shown in FIG. **2**. After the molding process is carried out, the mold is disassembled and the coil removed, all as is well understood in this art, and as previously indicated the manufacture of the coil itself is known to the art and is utilized in the present invention only in the total combination. It is essential that the inductance of the coil be accurately formed which requires that the turns be accurately held in the coil.

Forming the coil **18** as described is the first molding step and over molding with the cover **24**, which may be of the same molding compound as used for the coil **18**, is a second molding step. As has been described the molding of the cover **24** is carried out after the coil **18**, the insert **19**, the base nut **23** and the antenna clamp **21** are assembled together. This assures dimensional stability of the coil during the final molding step, allows use of less expensive, uninsulated wire for the coil itself and is compatible with automated assembly processes.

When assembled as described, the length of the whip **11** has been selected to extend to shoulder **14A** in antenna clamp **21**, the distance between point **14A** and the crimp at **31** and the length of terminal end **29** have been selected, the constants of the series of turns **27** have been selected, and the length of terminal end **32** to crimp at **33** has been selected in order to give the desired inductive value for cooperation with the appropriate matching impedance in the base **13** to be further described to assure that a voltage standing wave ratio of no greater than 2:1 throughout the Citizens Band is obtained by the antenna combination. Because of the accurateness with which the coil **18** may be formed, as described, and the dimensions of the other components selected, after final assembly at the factory no further adjustment of the inductive value, or of the assembled antenna are necessary.

According to one form of coil **18** as described, the wire was copper, the diameter of the turns from center to center of the wire was 0.750 inches, the wire size was 14 gage AWG, the distance between turns was 0.091 inch and the coil had 20 turns. Other combinations may of course be selected to be taken in combination with the antenna clamp and the length of whip etc.

The terminal end **29** of the coil **18** lies in a groove formed in the tapered end **20** of the insert **19**.

The base nut **23** is of course firmly held by the outer molded cover **24** and is provided with a threaded bore **49** which is force fitted onto the stub **20B** of the insert and is adapted to receive the threaded connecting screw **51** which forms part of the base **13**.

The collar **22** is of some relatively compliant material such as some form of rubber or elastomer, and includes a portion **30** of reduced diameter received in a corresponding opening at the upper end of the whip clamp member **21**. The collar **22** while compliant is still relatively stiff and prevents the whip **11** from bending sharply at the juncture **30A** where the whip member **11** in effect enters the metallic portion of the antenna clamp.

The antenna clamp **21** may be made of any suitable metal such as brass, for example, or Zamac, a well-known die casting type of material. Similarly for the material of the base **13**.

The base **13** comprises a metallic housing, or skirt, **52**, which may be of cast metal if desired. The base is open at the bottom as shown and is provided with a circular opening **53** at the top which has a diameter less than the outer diameter of the skirt **52** in order to form a shelf for resting against the attaching metal **54** of vehicle in the event that that is the mode of attachment of the antenna to the vehicle. Protuberances **53A** extend upwardly from the shelf to engage the undersurface of sheet metal **54**.

The connecting screw **51** includes a base portion **55** disposed within the skirt portion **52** and an insulating washer **56** is adapted to be disposed between the connecting screw stud portion **50** and the opening **53**. Interiorly of the skirt **52** there are a pair of embossments **57** and **57A**, the lower portion of which include slots **58**, **58A**, respectively. The base portion **55** of the connecting screw also has a slot or groove **59** for receiving conductors as will be described. The casting, or skirt **52**, includes an opening **61** through which the coaxial cable **62** to the Citizens Band radio is received. Spaced apart ears **63** extend from the casting **52** and are provided with bores **65** through which screws may be received for attaching the antenna base to the vehicle in this fashion. Sharp protuberances **67** may be provided on the interior surfaces of the ears **63** for assistance in this aspect.

The center conductor **69** of the coaxial cable **62** is crimped to the base **55** at the slot **59** and the braid or ground **71** of the coaxial cable is crimped to the embossment **57** at the slot **58** for example.

A capacitor **72** of appropriate capacitive value is disposed interiorly of the skirt, or casing, **52** and has two terminals or leads **73** and **74**. Lead **74** is attached to the base portion **55** by crimping in the slot **59** at **75**, for example, and the lead **73** is attached to the casting **52** as for example by crimping in the slot **58A** of embossment **57A** (FIG. **1B**).

The dielectric constant of the material encapsulating the coil **27** is between 2.4 and 3.8.

When the base portion **55**, the capacitor **72**, and the coaxial cable **62** are disposed in position and the connections as described are made, the space inside of the skirt **52** is filled with an epoxy compound. This completely encapsulates all of the components referred to and forms an integral unitary structure, hermetically sealing these components so that only a single contact point, namely the threaded stud **50** of screw **51** protrudes from the base for connection to the antenna proper. The encapsulation does not completely fill the space inside of skirt **52**. The remaining space is filled with a resilient member **52A**. The capacitor **72** forms part of an impedance matching network extending between the input coaxial cable **62** and the antenna loading coil **27** whereby a voltage standing wave ratio of no greater than 2:1 is maintained throughout the band, without further adjustment either at the factory, after assembly, or at the place of installation.

If the antenna is to be installed by attaching to the metal **54** of a vehicle, an opening **77** is provided therein through which the stud **50** of the connecting screw is received. Surrounding the stud **50** and extending through the opening **77** is a collar **64** forming part of insulating washer **56** as shown thereby insulating the center connector **51** from the vehicle metal. The threaded stud **50** is then received in an insulating nut **80** this nut then being screwed down until the antenna base is held securely against the under portion of the vehicle metal. An "O" ring **84** may be used to provide weatherproofing of the opening **77**. The portion of the threaded stud **50** protruding above the insulating nut **80** is then received in the threaded bore **49** of the antenna. The antenna is screwed down until the skirt portion **78** of the molded outer cover **24** bottoms on the flange **83** of the insulating nut **80**, which protects the painted finish of the vehicle metal from abrasion. If the antenna is attached to the vehicle by virtue of the ears **63** the antenna base is screwed to the projecting stud **51** until the lower edge of the skirt **78** engages the upper edge of skirt **52**. This gives the single point contact desired. In this manner of attachment, the insulating nut is eliminated.

Referring to FIG. **8**, the antenna circuit, as connected to a vehicle, is shown, the reference characters in FIG. **8** being the same for corresponding parts as in the previous figures described. Thus the antenna whip **11** is connected to the loading coil **27** which ends in a single connector, or base, nut **23**. The nut **23** receives the single stud **50** which is connected to the center conductor **69** of the coaxial cable **62** and the capacitor **72** has a lead **73** connected to the stud **50** and a lead **74** connected to ground. The capacitor **72** matches the inductive effect of the combined loading coil **27** and whip **11** to the impedance of the coaxial cable **62** throughout the frequency band.

In FIG. **9** the equivalent electrical circuit is shown and in this figure also the same reference characters are used for corresponding parts. The antenna whip **11** is shown as a capacitor **79** and radiation resistance **81**. The inductance of the loading coil **27** together with the capacitor **79**, corresponding to the antenna whip, give a net inductive effect which is balanced against the capacitance of the capacitor **72** in order to give impedance matching needed. At some point throughout the frequency band circuit comprising the capacitance **79** inductance **27** and the capacitance **72** will be resonant and at other frequencies the circuit will be removed from resonance but never sufficiently far to make the standing wave ratio greater than 2:1 throughout the whole frequency band.

According to one form of the invention described, the inductance value of the coil **27** was 5 micro henries, the capacitance value of the whip was 7 picofarads, and the capacitance value of capacitor **72** was 160 picofarads. The band width of the Citizen Band is 26.965 MHz to 27.255 MHz, and it is this band width that the constants set out in the foregoing specification have been selected for in order to give a standing wave ratio of not greater than 2:1 throughout the band width.

Other constants, of course, may be used, for other frequency bands, or conditions of operation.

We claim:

1. The method of forming an antenna for a predetermined frequency band comprising the steps of providing an accurate whip member of predetermined length, providing a loading coil having a predetermined number of turns, a predetermined diameter of turns, and a predetermined diameter of wire, interiorly molding said turns against the interior screw surface of a mold whose threads have the same diameters, pitch and groove diameter as the corresponding dimensions of said coil and forming for the length of said coil a hollow molded cylinder whose interior diameter is less than the interior diameter of said turns, providing an electrically insulating supporting member interiorly of said hollow molded cylinder and said coil and exteriorly thereof at

one end, providing an interconnecting metal member between one end of said whip member and said electrically insulating supporting member exteriorly of said coil, overmolding the assembly of said loading coil, the hollow molded cylinder, the electrically insulating supporting member exteriorly of said coil and the adjacent portion of said interconnecting metal member and attaching said whip member to said metal member.

2. An antenna for a predetermined frequency band comprising in combination a predetermined length of whip member, a loading coil of predetermined inductance, connected to said whip member for providing a precise inductive impedance of said whip and said coil for matching to a transmission line with a standing wave ratio of a value no greater than about 2:1 throughout the frequency band, said loading coil has a predetermined number of turns, a predetermined diameter of turns, a predetermined spacing between turns and the spacing of said turns is accurately predetermined, said predetermined accuracy of spacing of turns is maintained by interior injection molding a molding material against said turns while said turns are held against a threaded cavity whose turns correspond to those of said coil, said molding material comprising a hollow molded cylinder whose interior diameter is less than the interior diameter of said turns and whose exterior surface includes projecting embossments whose exterior diameter is at least equal to the exterior diameter of said turns, an electrically insulating supporting core member interiorly of said molding material and said loading coil throughout its length, a metallic whip positioning member disposed between one end of said whip member and one end of said loading coil, and an injection molded cover member surrounding said loading coil and a portion of said whip positioning member.

3. The antenna according to claim 2 wherein said core member includes a portion extending beyond one end of said loading coil, said metallic whip positioning member includes a base portion adjacent the extending portion of said core member and a whip receiving portion, and said injection molded cover member surrounds said loading coil, the extending portion of said core member and a whip receiving portion.

4. The antenna according to claim 3 including a compliant collar attached to the whip receiving portion of said whip positioning member for receiving one end of said whip member.

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